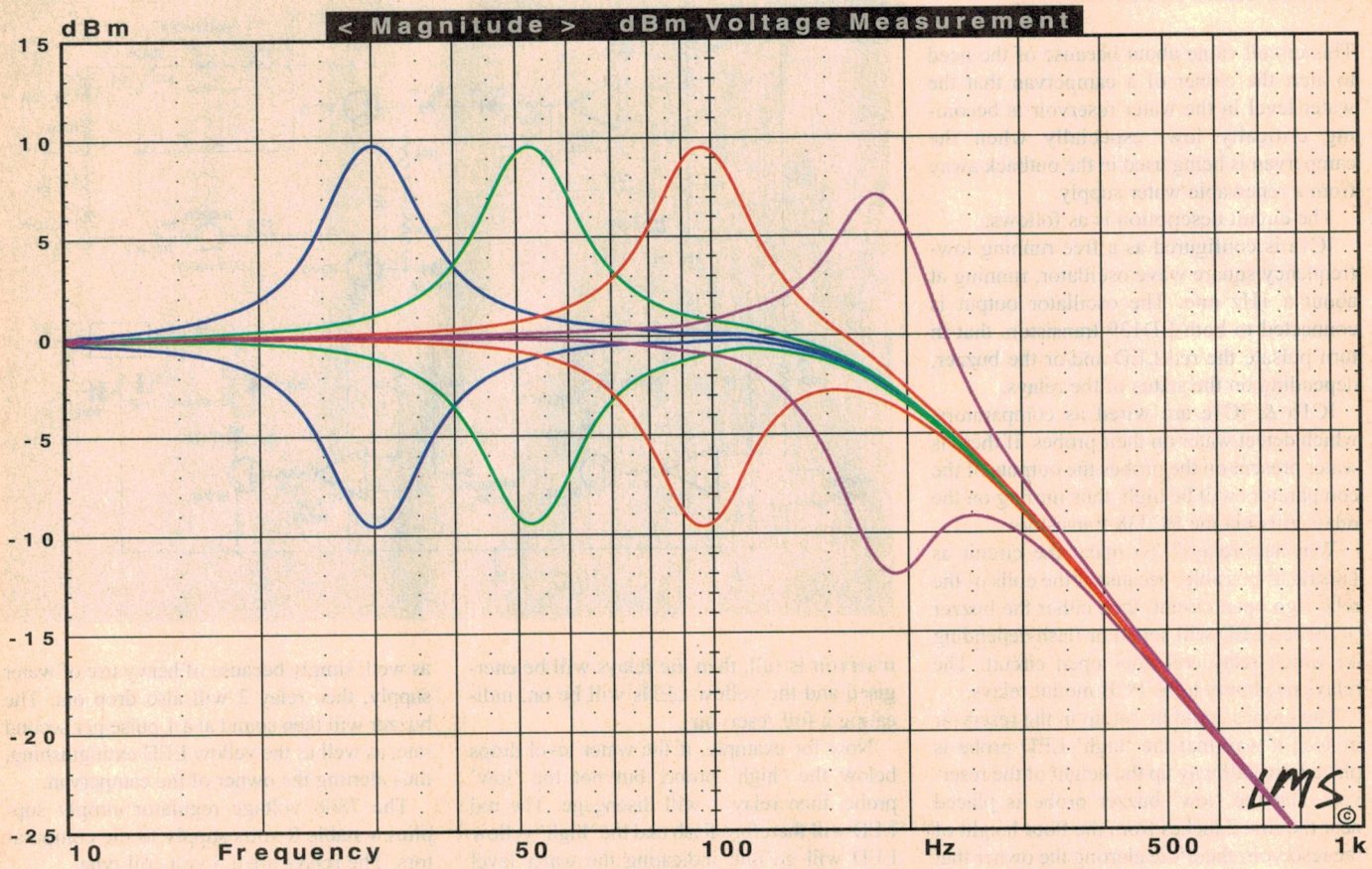
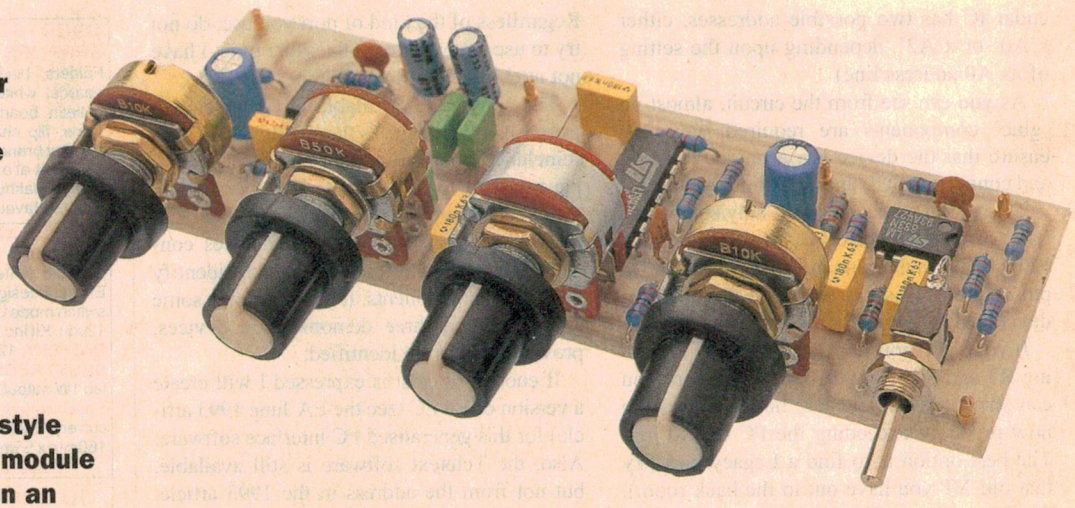
Sub-bass Processor



BY ROB EVANS

Get the most out of your low-bass speaker system, subwoofer or home theatre setup with this small but very effective audio 'toolkit' for low frequencies. Designed to both correct and enhance the low-end response of subwoofer-style speakers, this low-cost module can be easily installed in an existing amplifier or powered subwoofer, or just built up as a free standing unit.



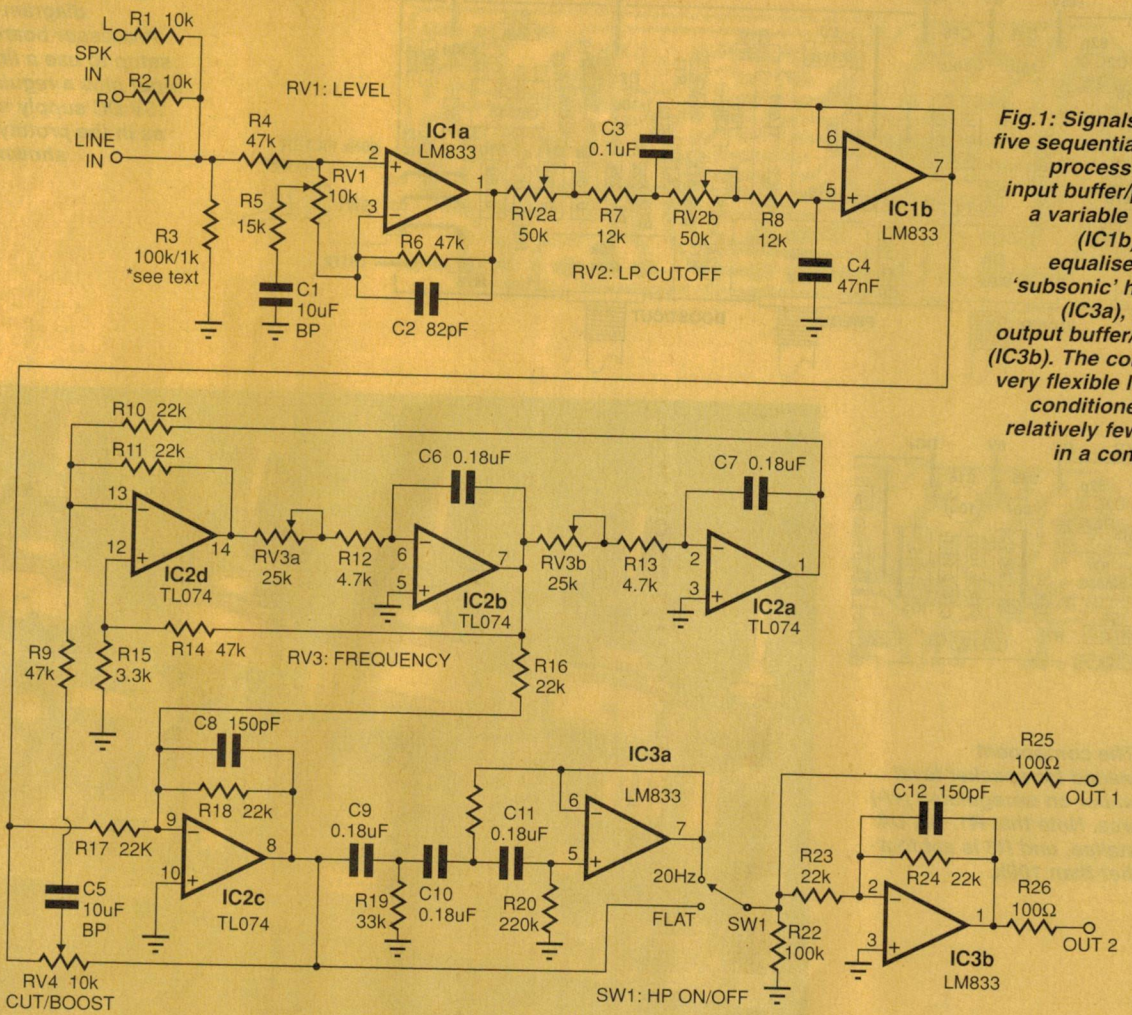


Fig.1: Signals pass through five sequential stages in the processor's circuit; an input buffer/preamp (IC1a), a variable low-pass filter (IC1b), a parametric equaliser (all of IC2), a 'subsonic' high-pass filter (IC3a), and finally, an output buffer/inverter stage (IC3b). The combination is a very flexible low-end signal conditioner, which uses relatively few components in a compact module.

If you've experienced the extra depth and impact of an audio system equipped with a dedicated low-bass speaker system, you're probably pretty keen to get one for yourself — if you haven't done so already. The aural improvement is often at its most dramatic in a home theatre system, where the soundtrack of recently-released feature films exploit the very low-end of the audio spectrum, to enhance the atmosphere and intensity of the on-screen action. It's riveting stuff, and part of what makes a full-sized cinema a memorable experience.

Dedicated low-frequency speakers can also work extremely well in hifi systems, of course, where small main speakers in particular benefit from the octave or so of bass extension added by a subwoofer. As ideal as this sounds though, when it comes to integrating a low-bass speaker into an existing system, many people find that they just don't get the smooth and extended low-end response they'd hoped for...

This lack of promised low-end performance can be due to a variety of factors, the most likely culprits being unfavorable room acoustics or a poor frequency response from the subwoofer itself. Even if a bass speaker sounded great in the hifi store and has response graphs to back this up, you're still likely to end up with a lumpy, soggy or lightweight bass performance thanks to the detrimental room dimensions.

Of course, moving the subwoofer to the centre of the room may help, but this is sure to be an 'unpopular' arrangement for others in the household. The way that a typical lounge room compromises the performance of dedicated low-frequency speakers really is their achilles heel, and no amount of heavy drapes or acoustic padding will really help — the low-frequencies just go straight through, and their long wavelengths continue to react directly with the room.

However in all but the most extreme cases of this problem, a moderate amount of equalisation applied in just the right frequency area can make a huge improvement in the system's low-end response. As you've probably gathered this is the basis of our new Sub-bass Processor presented here, which is specifically designed to condition low frequencies for sub-bass speaker systems.

Along with the equaliser, this small mod-

Specifications

High-pass (subsonic) filter:
20Hz cutoff.
-18dB/octave rolloff slope.

Low-pass (subwoofer) filter:
40Hz to 200Hz cutoff (variable).
-12dB per octave rolloff slope.

Lower frequency limit:
about 1Hz (HP filter switched out).

Gain: -12dB to +12dB (variable).

Equaliser:
12db boost or cut (variable).
30Hz to 190Hz centre frequency (variable).
Q of 5 (set by resistors).

Distortion and noise:
0.03% THD, -92dB unweighted (ref 1V)

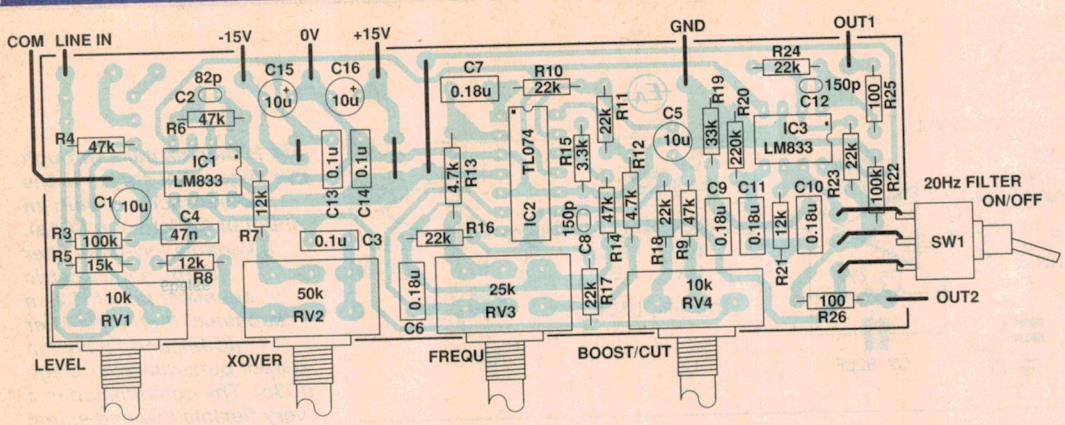
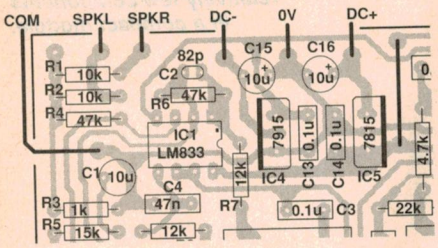


Fig.2 (left): The overlay diagram for the Processor board when setup to use a line-level input plus a regulated +/-15V DC supply source - as in the prototype unit shown below.



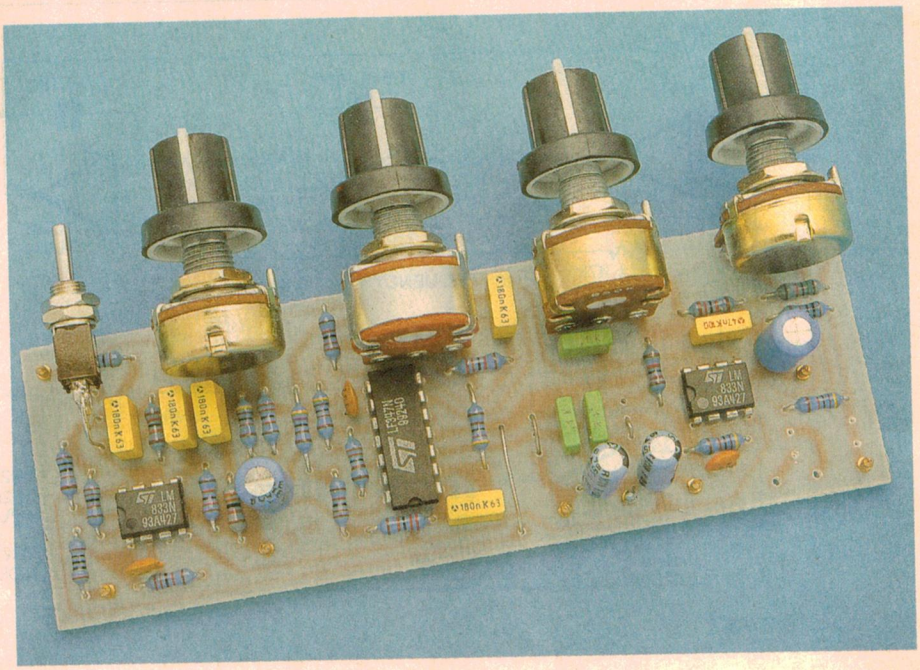


Fig.3 (above): The component arrangement needed for speaker-level input signals and/or an unregulated (+/-) DC supply source. Note that R1, R2, U4 and IC5 are installed, and R3 is set to a value of 1k rather than 100k.

ule includes a 'bypassable' subsonic filter set to 20Hz, a variable low-pass (subwoofer) filter, a variable gain (+/-12dB) input stage, plus dual-phase outputs for running amplifiers in bridged mode. As you can see, we've managed to put a lot of function into a small package.

When connected in the signal path to a low-bass amplifier/speaker combination, the Sub-bass Processor can be used to improve the system's performance in a wide variety of ways, as you can see from the associated graphs. By careful adjustment, you can compensate for a poor or 'peaky' subwoofer response, improve the low-end extension in a speaker that rolls off earlier than you'd like, and even reduce a subwoofer driver's cone travel (and therefore improve its power handling) without compromising its sound quality.

This last achievement is mostly thanks to the unit's relatively steep (-18dB/octave) subsonic filter, which greatly reduces inaudible and potentially damaging signals below 20Hz. When switched in, it can literally save a driver from flapping itself to death — particularly when a very low-frequency boost has been dialed up.

Regardless of any applied equalisation though, frequencies below around 20Hz can be bad news for drivers in ported enclosures, since the driver cone becomes 'unloaded' at frequencies below the port tuning point. The lack of a controlling force on the cone leads to excessive travel, and quickly leads to mechanical damage. This applies to the majority of subwoofers by the way, which are invariably of a bass-reflex or bandpass (vented) design.

Whether the processor is installed in its own box or perhaps inside an existing amplifier really depends on your own particular needs. The module itself is quite small, and you shouldn't have too much trouble finding a spot for it.

It can be driven from speaker- or line-level input signals, but the most likely way is probably from the mono subwoofer/effects output on the rear of a home theatre amplifier. Also, it really doesn't matter if it's driving a powered subwoofer that's already equipped with a low-pass filter, since the processor's own filter can be wound out to to its maximum frequency where it will have little effect.

Circuit details

The processor's circuit can be broken down into five cascaded stages, where each has quite a separate and defined job. Moving through the signal path as shown in the schematic diagram (Fig.1), these are; an input buffer/gain stage (IC1a), a variable low-pass filter (IC1b), the parametric equaliser (all of IC2), a fixed 20Hz high-pass filter (IC3a), and finally, an inverter/buffer output stage (IC3b). Three opamp chips are used in total (two dual LM833's and one TL074 quad), while all chips are powered from a common +/-15V supply rail.

Starting at the input stage, line level signals are applied directly to IC1a at R4, while speaker level signals (if that option is used) are first attenuated by R1 and R2 in conjunction with R3. Note that R3 has a value of 100k when the line level input is used, but must be a 1k resistor when using the speaker level inputs. In this way, the high level signals from an amplifier's speaker outputs are attenuated by around 20dB.

The input stage itself can be varied in gain over a range of +/-12dB by RV1, which is

placed across the opamp's inputs in a slightly unusual configuration. Here, the pot varies both the input attenuation (at R4) and the opamp's negative feedback (at R6), in an inverse relationship.

Note that the network values have been chosen for a maximum boost and cut of 12dB (a gain of 4 or 0.25), while the circuit is in balance with the pot in its centre position, resulting in a stage gain of one (0dB). Also, R5 is AC-coupled to ground to prevent DC voltage-induced pot noise, and C2 reduces the stage gain at above-audio frequencies.

IC1a's output is then applied directly to the following low-pass filter stage based on IC1b, which is a two-pole arrangement with a rolloff slope of -12dB per octave. The cut-off point can be varied from around 40Hz to 200Hz by the dual 50k pot RV2.

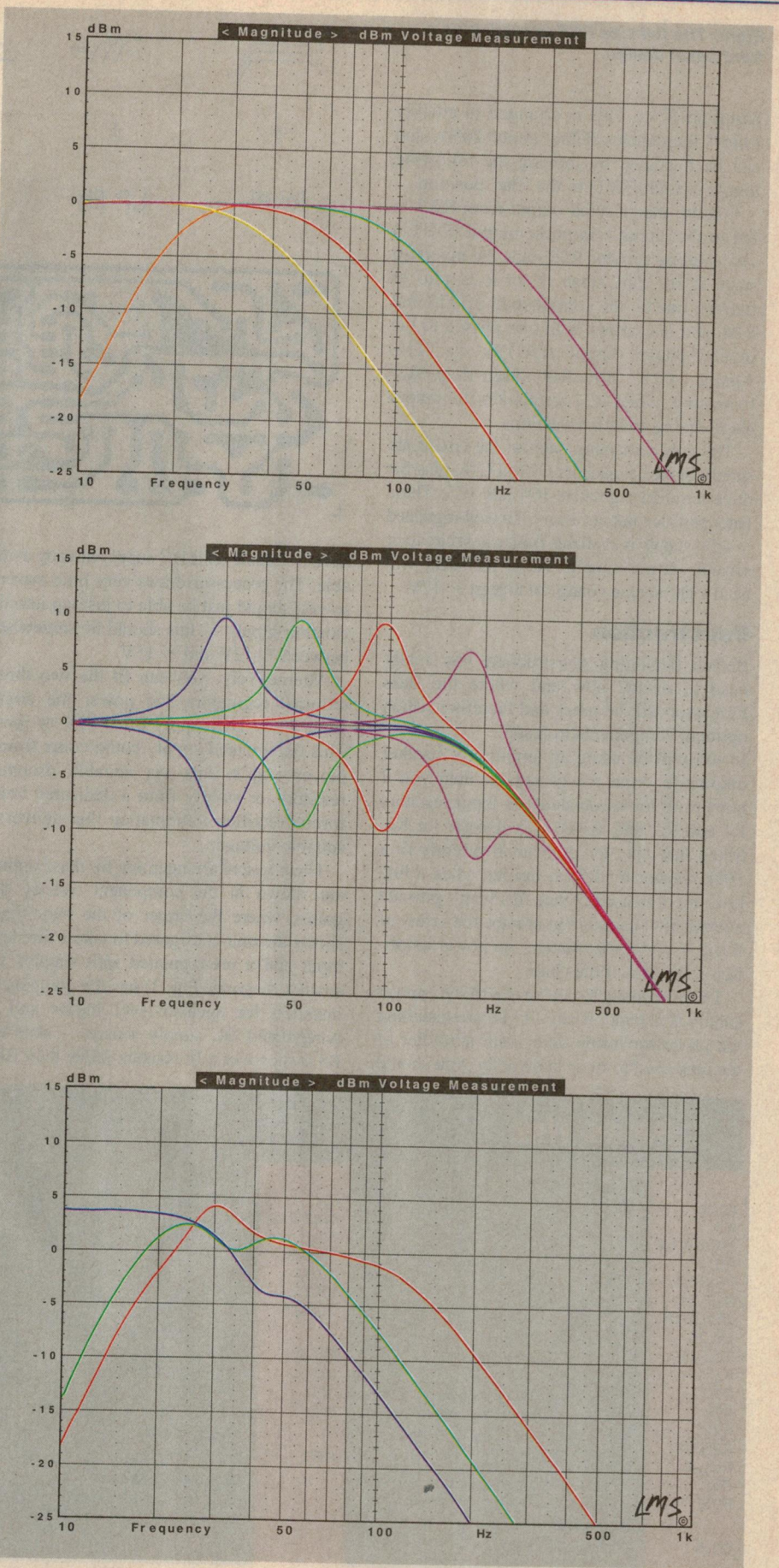
Next in line is the parametric equaliser stage based on a TL074 quad opamp, IC2. This is relatively standard state-variable filter circuit where multiple feedback paths are used around two single-pole filter stages (IC2b and IC2a). Both the positive and negative feedback networks create a controlled-Q bandpass output at IC2b (pin 7), which is then mixed with the input signal at the simple inverting/mixer stage IC2d.

The trick here is that the parametric's input stage (IC2d) is fed by the cut/boost pot RV4, which varies the take-off point between the input and output of IC2c. As this is an inverting opamp stage, the *phase* of the signal sent to the parametric is varied over a 180° range by RV4, causing the re-mixed bandpass signal subtract from or add to the original — or in effect, cut or boost that frequency area.

As before, a dual pot (RV3) is used to move the filter frequency to the desired point, C5 AC-couples the RV4's wiper to prevent noise, and C8 reduces the stage gain at above-audio frequencies. Along with the frequency, plus degree of cut and boost, the parametric filter's Q (or bandwidth, in effect) can also be controlled.

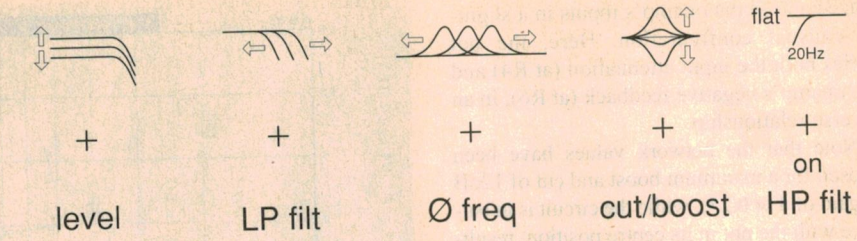
In our prototype this has been set to a value of around five by the 47k resistors R9 and R14, but the shape may be a little sharp for more gentle equalising jobs. These two resistors values can be varied as needed, where for example, a value of 27k would result in a Q value of about three. The equation $Q = (Rq/R15 + 1)/3$ can be used as a guide, where Rq is the value of R9 and R14, and R15 is 3.3k as shown.

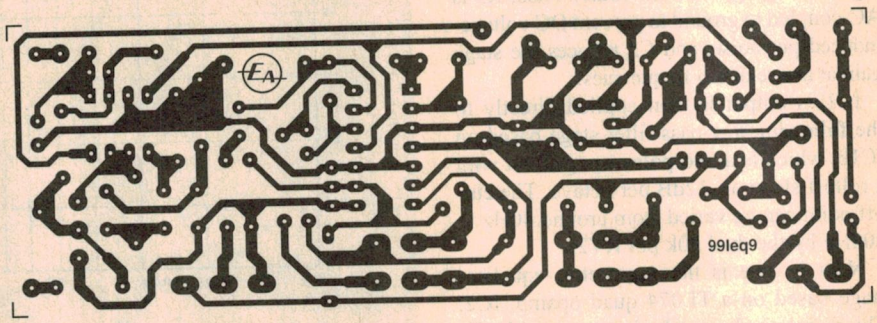
The equalised signal is next passed to a conventional three-pole high-pass filter



Right: Measured response plots from the Processor, showing (top to bottom) the HP (subsonic) and LP filters, the parametric equaliser, and how these (plus the level control) combine to a composite correction curve.

Right: The full-size PCB artwork plus a front panel design.





based on IC3a. This is arranged to quickly rolloff frequencies below about 20Hz, and can be bypassed by moving the following toggle switch (SW1) to the 'flat' position.

Finally, the selected output from SW1 is fed to the circuit's in-phase output (OUT1) via isolating resistor R25, plus the inverting stage IC3b. This stage is set to a gain of (minus) one by the combination of R23 and R24, and it's output is in turn passed to the inverse-phase output (OUT2) via R26. Again, C12 provides high-frequency bypassing, while R22 terminates the output stage during switch transitions.

The only remaining parts of the circuit are supply bypass capacitors C13 to C16, plus the three terminal regulators IC4 and IC5. These latter parts are not necessary if a well-regulated +/-15V supply is available from a host circuit or separate power supply, but if included, will need a DC source voltage of at least +/-17V.

Construction

Before beginning construction you really need to decide how and where the Bass Processor will be used, and therefore which optional components to install.

If you will be using an amplifier's speaker outputs to drive the processor, then you'll need to fit the associated 10k input resistors R1 and R2, and install a 1k resistor for R3. Make sure that you don't inadvertently fit a 100k resistor for R3 (as needed when a line level input is used), since this won't provide enough attenuation to guarantee the safety of IC1a — or for that matter, the power amplifier at the end of the chain.

The other point to decide is what DC power supply is at hand, if any. If you are installing the processor inside your main amplifier or the amp used to run a subwoofer, you should have a suitable split DC supply already available. The processor draws very little current, so you should just be able to just tap into the existing supply — this should lie somewhere between +/-12V and +/-15V.

Alternatively, you can fit the two three-terminal regulators and power the circuit from a raw DC supply of +/-17V or more. This unregulated supply could come from a power amp's rails via suitable dropping resistors, or simply from a dedicated transformer/rectifier combination that delivers a suitable voltage.

The physical arrangement for these options are shown in the component overlay diagrams, where the larger of the two (Fig.2) shows the unit configured to take a line-level input and a pre-regulated split supply. The smaller diagram (Fig. 3) has the components installed for speaker-level inputs and an unregulated DC supply source — note that R3 is shown as a 1k resistor, rather than 100k.

With the configuration decisions out of the way, the components can fitted to the PCB (coded 99leq9, measuring 115 x 40mm) while referring to the overlay diagrams as a guide. If you're using the close-tolerance multi-banded resistors, it may pay to check the value of each with a multimeter as they're installed. And as usual, pay close attention to the polarity of the ICs and electrolytic capacitors.

The only other points to note are that the pots should be pushed firmly down onto the board before soldering so that the shafts neatly line up, and filter on/off switch can be suspended on wire stalks (as in the prototype) so that it too matches that alignment.

Checking out

With the processor board completed you can now connect a DC supply and make a couple of initial tests — take care with the supply polarity here, and don't neglect to connect the 0V (common) line from the DC source. First check that the output of each stage is close to zero volts, and if not, quickly remove the power and re-check your work.

If all's well though, the next test is to try the circuit out with an audio input from a convenient music source, while monitoring the results at one of the outputs (OUT1 or OUT2). The controls should all make sense if the circuit is functioning correctly, and you should soon get a feel for how they can be used to tailor low-frequency signals.

If you're confronted by a stony silence at this point, you can quickly zero in on the area of concern by just progressively monitoring the output from each stage, starting with the input itself. By the way, as you're moving the monitor amp's input lead from stage to stage make sure that its earth or common point stays connected to the processor circuit's 0V line, otherwise you'll probably just hear a series of ungracious 100Hz blurts. ❖

Parts list

Resistors

R1,2	10k
R3	1k
R4,6,9,14	47k
R5	15k
R7,8,21	12k
R10,11, 16,17,18, 23,24	22k
R12,13	4.7k
R15	3.3k
R19	33k
R20	220k
R22	100k
R25,26	100 ohms
RV1,4	10k single pot, linear
RV2	50k dual pot, linear
RV3	25k dual pot, linear

Capacitors

C1,5	10uF bipolar electro
C2	82pF ceramic
C3,13,14	0.1uF MKT
C4	47nF MKT
C6,7,9, 10,11	0.18uF MKT
C8,12	150pF ceramic
C15,16	10uF 25V electro

Semiconductors

IC1,3	LM833 dual opamp
IC2	TL074 quad FET opamp
IC4	7915 -15V regulator (optional)
IC5	7815 +15V regulator (optional)

Switches

SW1	SPDT mini toggle

Miscellaneous

PCB coded 99leq9, 115 x 40mm; four small knobs, PCB pins.